

Effect of microflora and lactose on the absorption of calcium, phosphorus and magnesium in the hindgut of the rat

Claude ANDRIEUX, E. SACQUET

*Laboratoire des Animaux sans Germes, C.N.R.S.,
I.N.R.A., 78350 Jouy-en-Josas, France.*

Summary. For 4 weeks, 3-month old germfree (GF) and conventional (CV) rats were given a semi-synthetic diet sterilized by irradiation with or without 10 % of lactose. During the 5th week, 0.2 % of titanium oxide (TiO_2) was added to the diet and the rats were killed at regular intervals throughout the light/dark cycle. The patterns of TiO_2 and ^{45}Ca excretion were similar, indicating that TiO_2 was a good marker of unabsorbed calcium transit. The apparent absorption coefficient of calcium, magnesium and phosphorus was determined in the ileum, caecum, large intestine and faeces by the mineral/ TiO_2 ratio. The effects of microflora and lactose varied with the mineral and the digestive tract level studied.

— In the small intestine, microflora had no effect on the apparent absorption of calcium and magnesium but did have an unfavorable influence on phosphorus absorption. Lactose increased calcium and magnesium absorption, and this increase was similar in GF and CV rats, but lactose had a favorable effect on phosphorus absorption only in CV rats.

— In the caecum, microflora had an unfavorable effect on the apparent absorption of calcium and magnesium and a favorable effect on phosphorus absorption. The ingestion of lactose reduced calcium and magnesium absorption in the caecum of GF rats and phosphorus absorption in the caecum of CV animals.

— In the colon, mineral absorption was not significant in either CV or GF rats receiving the lactose-free diets. Lactose ingestion caused the absorption of calcium, magnesium and phosphorus to rise significantly only in GF rats. This absorption contributed to the stronger effect of lactose on total calcium and phosphorus absorption in GF rats.

Introduction.

We reported previously (Andrieux, Sacquet and Guéguen, 1982) that lactose increases the absorption and retention of calcium and phosphorus more in adult germfree (GF) than in adult conventional (CV) rats. In the voluminous caecum of GF rats, lactose increases the amount of calcium that is soluble and, hence, that which is liable to be absorbed. This observation led us to suppose that there might be calcium absorption in the hindgut of GF rats which would explain the differences in apparent absorption between GF and CV rats both fed a lactose diet.

The present paper reports a study of the apparent absorption coefficient of calcium, magnesium and phosphorus in the ileum, caecum, colon and faeces of GF and CV rats. We used titanium oxide (TiO_2), an unabsorbable marker (Fournier, 1950), and first gave it in the diet long enough to establish an equilibrium between its ingestion and faecal excretion. Apparent absorption of the minerals was determined by measuring the mineral/marker ratio throughout the light/dark cycle. This paper assesses the value of the method and the results obtained.

Material and methods.

Animals and diet. — We used GF and CV rats of Fischer strain 344 that had been fed a commercial diet. At 3 months of age, they were fed a semi-synthetic diet with 10 % of lactose (L) or without (LO) (table 1). At 15 weeks, they were put into metabolism crates and at 16 weeks were fed the L or LO diet to which we had added 0.2 % of TiO_2 . The diets, sterilized by gamma irradiation at 40 kilo-Gray in vacuum-sealed plastic bags, were given *ad libitum* in the form of a paste containing 60 % of water.

Method used for measuring apparent absorption.

Rationale. — The method we used to measure apparent absorption of minerals was derived from a classical method for studying net nutriment utilization (Kotb and Luckey, 1972) which consists in incorporating a transit marker for a long enough time so that marker excretion equals marker ingestion. Apparent absorption is then determined by comparing nutriment/dietary transit marker ratios in the faeces and at different levels of the digestive tract.

This method was used in 1967 by Ali and Evans to study the effect of lactose on the apparent absorption of calcium. In their experiment, the rats were all killed at the same time of day. Therefore, the results were only valid if the rate of marker and of mineral transit was the same and if apparent absorption remained constant during the light/dark cycle.

To fulfill these two conditions, we studied the effectiveness of TiO_2 as a calcium marker on the one hand and changes in the ratio $R = \frac{\text{mineral}}{\text{TiO}_2}$ over a 24-hour period (entire cycle of dietary rhythm) on the other.

TABLE 1
Diet composition (%)

Maize starch	58
Casein	20.5
Maize oil	9
Cellulose	5
* Mineral mixture	4.5
Additional vitamins and aminoacids	3

The complete diet contained the following mean amounts of minerals (in mg/g drymatter) : Ca : 7.4, P : 6.7, Mg : 0.64.

* In Andrieux, Sacquet and Guéguen, 1982.

Finally, because it was impossible to determine if variations in R were due to variations in apparent absorption, to differences in transit rate between marker and mineral or to chance, we computed the arithmetic mean of all the R values found and their standard deviation. This mean (\bar{R}) was used to compute mean apparent absorption (\bar{A}) at different levels of the digestive tract (ileum, caecum, colon) for 24 h. Thus, mean apparent absorption (\bar{A}) from ingestion to a level N of the digestive tract was expressed in % of ingested matter I.

$$\bar{A} (\text{intake} - \text{level N}) = \left(1 - \frac{\bar{R} \text{ level N}}{\bar{R} \text{ diet}}\right) \times 100$$

The results, expressed as the mean \pm SD, were analyzed by the method of Newman and Keuls, modified by Duncan (1955).

Marker effectiveness was checked in experiments 1, 2 and 3. Apparent absorption at different digestive tract sites was measured in the various lots in experiment 4.

Experiment 1. — On one night, 4 GF and 4 CV rats received diet L or LO containing 0.2 % of TiO_2 and 0.005 μCi of ^{45}Ca /g of diet. Daily TiO_2 and ^{45}Ca excretions were measured in the faeces for 10 consecutive days.

Experiment 2. — At 4 p.m., 1 GF rat was fed 40 mg of TiO_2 and 0.25 μCi of ^{45}Ca in 2 g of diet L and 1 GF rat was fed 40 mg of TiO_2 and 0.25 μCi of ^{45}Ca in 2 g of diet LO. Since the rats had been trained previously, they ingested the diets in 10 min and were then given the diets without the transit marker. The $^{45}\text{Ca}/\text{TiO}_2$ ratio was measured in the faeces.

Experiment 3. — For 7 days, 2 CV rats were given diet L containing 0.2 % of TiO_2 . During this time we measured daily TiO_2 excretion. On day 7, we measured the amounts of TiO_2 , calcium, magnesium, phosphorus and other minerals in each faecal pellet excreted during the light/dark cycle.

Experiment 4. — For 7 days, 32 GF and 32 CV rats were given either diet L or LO containing 0.2 % of TiO_2 . During this time, we measured daily TiO_2 excretion. On day 7, we measured the amounts of TiO_2 , calcium, magnesium and phosphorus ingested and excreted. On the 8th day, 16 rats of each lot (CVLO, CVL, GFLO, GFL) were killed in pairs every 3 h for 24 h. We sampled the last 10 cm of the small intestine, caecum and colon. The digestive contents and faeces of day 7 were homogenized and oven-dried. The TiO_2 and minerals were determined from the ash obtained.

Analytical methods. — The TiO_2 insoluble in strong acids and bases, was easily separated from the calcium and the other minerals after the samples had been ashed as follows. 100 to 200 mg of dry matter were ashed at 550 °C for 16 h. This ash was re-dissolved in 10 % hot HNO_3 and the insoluble TiO_2 was separated from the other minerals by centrifugation at 35 000 \times g for 10 min. All the minerals, except P, were assayed in the supernatant by atomic absorption spectrometry (apparatus IL151). Phosphorus was assayed by Misson's reaction. The TiO_2 was mixed in potassium sulfate acid and dissolved at 100 °C in $\text{H}_2\text{SO}_4 2\text{N}$. The addition of H_2O_2 caused a staining reaction proportional to the

amount of TiO_2 . Staining intensity was determined at 410 nm. This method revealed the marker when 10 μg or more of it was present.

Results.

1) Effectiveness of TiO_2 as a mineral transit marker.

a) Recovery of ingested TiO_2 .

Experiment 1. — After the diets containing 0.2 % of TiO_2 had been ingested for one night, the recovery rate of the marker (in % of ingested diet \pm SD for 2 rats per lot) equalled 105.9 ± 5.0 (CVLO), 101.2 ± 3.8 (CVL), 100.4 ± 5.2 (GFLO), 103.4 ± 2.8 (GFL) or 102.7 ± 2.4 for the 8 rats. This recovery rate was not affected by the type of rat or the diet.

Experiment 2. — The 2 rats receiving 40 mg of TiO_2 at a given time excreted 104.5 and 103 %, respectively, of the ingested TiO_2 .

Experiment 4. — On day 7 of the ingestion of TiO_2 -marked diets, marker recovery rate of the 64 rats averaged 103.0 ± 1.4 %.

b) Comparative transit of TiO_2 and ^{45}Ca .

Experiment 1. — The patterns of TiO_2 and ^{45}Ca excretions were exponential. The ratio of the slopes of the straight lines obtained in semi-logarithmic coordinates averaged 1.001 ± 0.007 (means of 8 rats \pm SD).

Experiment 2. — The analysis of each faecal pellet excreted during the excretion of a given dose of TiO_2 and ^{45}Ca showed that the $^{45}\text{Ca}/\text{TiO}_2$ ratio was constant in the faeces during the light/dark cycle and throughout excretion of the markers (fig. 1).

Experiment 3 (table 2). — In rats ingesting TiO_2 for 7 days, individual analysis of the faecal pellets excreted on day 7 by 2 CVL rats over a 24-hour period showed that the coefficient of variation $\left(\frac{\text{SE}}{\text{mean}} \times 100\right)$ of the ratio $R \left(\frac{\text{mineral}}{\text{TiO}_2}\right)$ was less than 5 % for calcium and less than 10 % for phosphorus, magnesium,

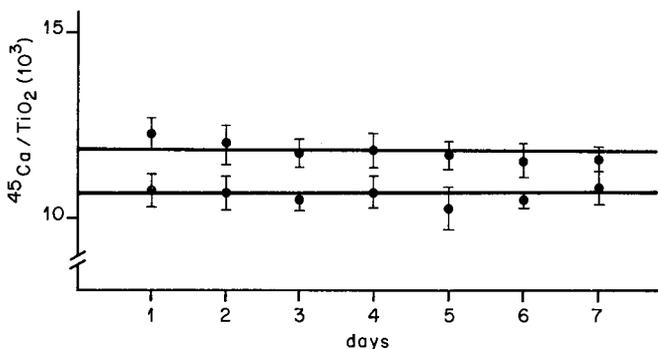


FIG. 1. — $^{45}\text{Ca}/\text{TiO}_2$ ratio in the faeces during excretion of a single dose of ^{45}Ca and TiO_2 . (Each point is the mean of $^{45}\text{Ca}/\text{TiO}_2$ of each faecal pellet excreted over 24 h \pm SD.)

TABLE 2
Variation in the mineral/TiO₂ ratio of each faecal pellet of 2 CVL rats over a 24-hour period (mean ± SE)

	Ca/TiO ₂	V	Mg/TiO ₂	V	P/TiO ₂	V
rat n° 1	2.21 ± 0.07	3.2	0.131 ± 0.010	7.5	1.15 ± 0.07	6.1
rat n° 2	2.06 ± 0.08	3.9	0.133 ± 0.008	6.0	1.26 ± 0.10	8.0
	Mn/TiO ₂ 10 ⁻³	V	Zn/TiO ₂ 10 ⁻³	V	Fe/TiO ₂ 10 ⁻³	V
rat n° 1	35.5 ± 2.4	6.8	21.1 ± 1.4	6.6	74.1 ± 3.8	5.1
rat n° 2	36.3 ± 3.1	8.5	21.6 ± 0.8	3.7	78.5 ± 4.7	5.9
					Cu/TiO ₂ 10 ⁻³	V
					5.5 ± 0.4	7.2
					5.3 ± 0.4	7.0

V : coefficient of variation = $\frac{SE}{mean} \times 100$.

manganese, zinc, iron and copper. These results demonstrate that TiO_2 was effective in marking the transit of the unabsorbed minerals.

2) Variations in the Ca/TiO_2 ratio at different levels of the digestive tract during the light/dark cycle (figs. 2, 3, 4, 5) (Experiment 4).

Figures 2 to 5 show the changes in the ratio $R = \frac{Ca}{TiO_2}$ at different levels of the digestive tract. In the ileum, the ratio (RI) varied more than in the caecum

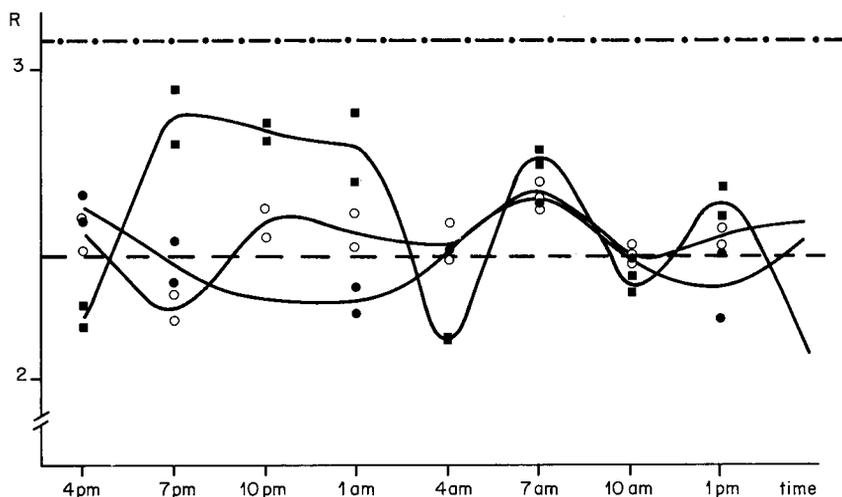


FIG. 2. — Pattern of the Ca/TiO_2 ratio (R) during the light/dark cycle in the ileum ■, caecum ○, colon ● of CVLO rats. Average value in the diet —●—, average value in the faeces —●—

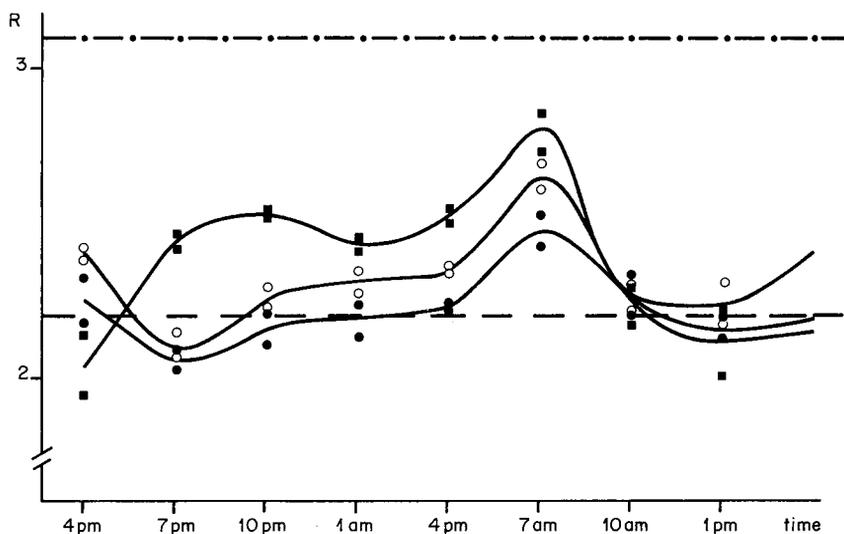


FIG. 3. — Pattern of the Ca/TiO_2 ratio (R) during the light/dark cycle in the ileum ■, caecum ○, colon ● of CVL rats. Average value in the diet —●—, average value in the faeces —●—

(RC) or colon (RLI) during the light/dark cycle. The highest RI values in all rat lots were found between 7 p.m. and 7 a.m., when diet intake occurred. On the other hand, from 10 a.m. to 4 p.m., low RI values were observed for CVLO, CVL and GFLO rats. In GFL rats, the RI remained constant during almost all the light/dark cycle.

In the caecum, the highest RC values were found at 7 a.m. in CV rats and at 10 a.m. in GF rats, whether they received lactose or not. However, lactose increased the maximal RC value of CV and GF rats.

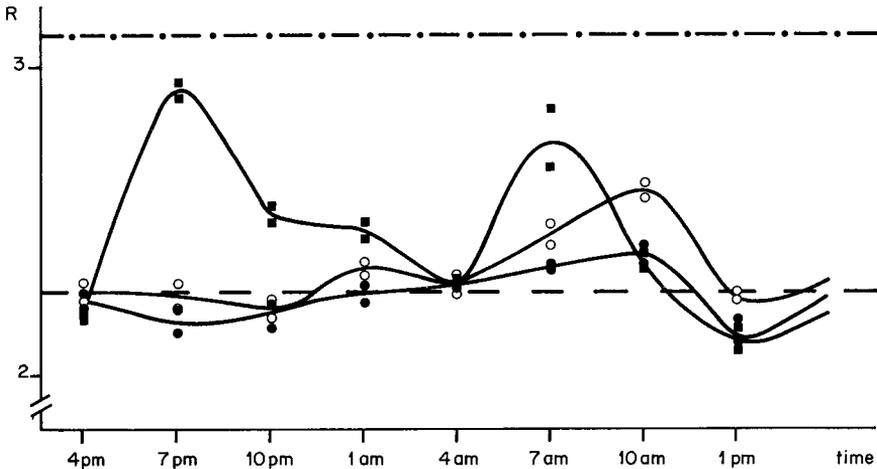


FIG. 4. — Pattern of the Ca/TiO_2 ratio (R) during the light/dark cycle in the ileum ■, caecum ○, colon ● of GFLO rats. Average value in the diet —●—, average value in the faeces —■—.

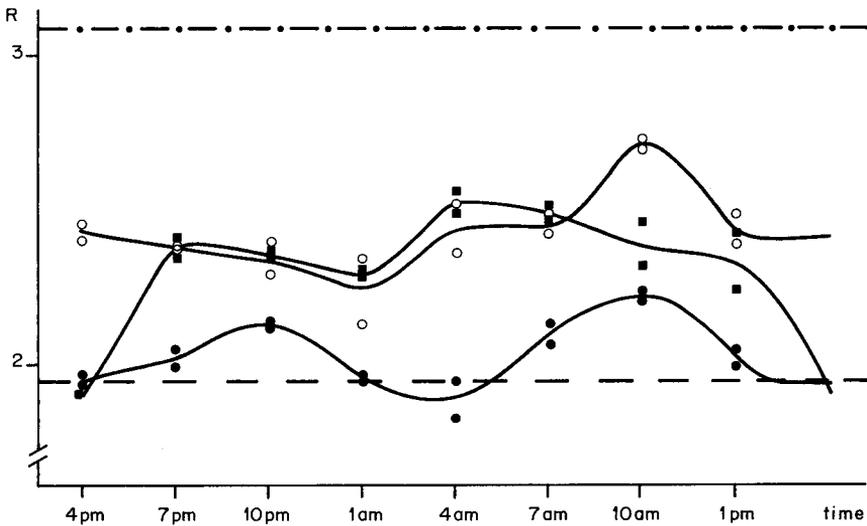


FIG. 5. — Pattern of the Ca/TiO_2 ratio (R) during the light/dark cycle in the ileum ■, caecum ○, colon ● of GFL rats. Average value in the diet —●—, average value in the faeces —■—.

In the colon, the RLI was also highest at 7 a.m. in CV rats and at 10 a.m. in GF rats.

The pattern of the P/TiO₂ and Mg/TiO₂ ratios resembled that of the Ca/TiO₂ ratio, *i.e.* high RI between 7 p.m. and 7 a.m., maximal RC at 7 a.m. in CV rats and at 10 a.m. in GF animals. Variation amplitude depended on the mineral and the site studied.

3) Apparent mineral absorption at different levels of the digestive tract.

Calcium (table 3). — The apparent absorption of calcium from intake to the ileum was comparable in CVLO and GFLO rats. Calcium was not absorbed in the caecum or colon of CVLO rats ; in GFLO rats, calcium absorption was significant in the caecum but not in the colon. Total calcium absorption was comparatively higher in GFLO than in CVLO rats, the difference being in the caecum.

The ingestion of lactose caused a similar increase in calcium absorption in the small intestine of both CV and GF rats. Lactose had no significant effect in the caecum or colon in CV rats. High calcium absorption was found in the colon of GF animals. Thus, lactose had a much stronger effect on total calcium absorption in GF than in CV rats.

Phosphorus (table 4). — The rate of phosphorus absorption from intake to the ileum was higher in GFLO than in CVLO rats. In the latter, this absorption

TABLE 3

Apparent absorption of calcium (in % of intake) from intake to ileum, caecum and colon and total apparent absorption
(n = 16 per lot) (mean ± SD)

Rats and Diet	CVLO	CVL	GFLO	GFL
Intake-ileum	19.0 ± 10.5 ^d	23.7 ± 9.2 ^{bc}	19.7 ± 8.7 ^d	26.0 ± 6.4 ^{bc}
Intake-caecum	21.0 ± 4.2 ^d	25.5 ± 5.2 ^{bc}	24.5 ± 4.1 ^{bc}	22.2 ± 5.2 ^{cd}
Intake-colon	22.9 ± 5.2 ^{cd}	28.7 ± 4.8 ^b	27.4 ± 2.9 ^b	35.5 ± 4.2 ^a
Intake-faeces (total apparent absorption)	22.6 ± 3.5 ^{cd}	28.4 ± 2.9 ^b	27.7 ± 1.6 ^b	37.4 ± 2.9 ^a

Values with the same script were not significantly different at 5 % according to the Newman-Keuls test.

TABLE 4

Apparent absorption of phosphorus (in % of intake) from intake to ileum, caecum and colon and total apparent absorption
(n = 16 per lot) (mean ± SD)

Rats and Diet	CVLO	CVL	GFLO	GFL
Intake-ileum	34.4 ± 11.4 ^d	50.1 ± 9.3 ^{bc}	48.7 ± 12.0 ^{bc}	54.1 ± 11.4 ^b
Intake-caecum	47.7 ± 5.4 ^c	52.7 ± 3.2 ^b	53.4 ± 5.0 ^b	56.3 ± 4.7 ^b
Intake-colon	46.9 ± 5.7 ^c	54.8 ± 2.1 ^b	54.0 ± 3.6 ^b	61.6 ± 4.3 ^a
Intake-faeces (total apparent absorption)	47.6 ± 3.4 ^c	53.0 ± 2.5 ^b	53.0 ± 3.5 ^b	61.2 ± 1.8 ^a

Values with the same script were not significantly different at 5 % according to the Newman-Keuls test.

was significant in the caecum but it was not significant in GFLO animals. Total phosphorus absorption, however, was higher in the GFLO than in the CVLO rats.

The ingestion of lactose diets increased phosphorus absorption more in the small intestine of CV than of GF rats, and thus the rate of phosphorus absorption was comparable to that in the ileum of CVL and GFL rats.

Rats fed lactose did not absorb a significant amount of phosphorus in the caecum. Phosphorus absorption in the colon was higher in GFL than in CVL rats.

Total phosphorus absorption was augmented by lactose in both CV and GF rats. In CV animals, lactose had an effect in the small intestine, while in GF rats that effect was in the hindgut.

Magnesium (table 5). — In CVLO and GFLO rats, apparent absorption of magnesium from intake to the ileum was similar. In the caecum, apparent absorption of magnesium was significant in both CVLO and GFLO rats, but was higher in the latter. No significant absorption was found in the colon of either CVLO or GFLO rats. Total magnesium absorption was much higher in GFLO than in CVLO animals, the difference being entirely due to better magnesium absorption in the caecum of GFLO rats.

TABLE 5

Apparent absorption of magnesium (in % of intake) from intake to ileum, caecum and colon and total apparent absorption
(n = 16 per lot) (mean \pm SD)

Rats and Diet	CVLO	CVL	GFLO	GFL
Intake-ileum	26.1 \pm 7.5 ^e	45.0 \pm 14.0 ^d	27.1 \pm 2.1 ^e	41.1 \pm 7.6 ^d
Intake-caecum	42.5 \pm 6.6 ^d	54.7 \pm 8.4 ^c	64.1 \pm 4.5 ^b	63.1 \pm 5.9 ^b
Intake-colon	45.6 \pm 8.4 ^d	59.5 \pm 5.6 ^{bc}	66.2 \pm 3.8 ^b	72.5 \pm 5.9 ^a
Intake-faeces (total apparent absorption)	43.9 \pm 4.2 ^d	57.4 \pm 4.5 ^c	63.0 \pm 4.1 ^b	72.8 \pm 3.1 ^a

Values with the same script were not significantly different at 5 % according to the Newman-Keuls test.

In the small intestine, lactose caused a similar increase in apparent absorption of magnesium in both CV and GF rats. Magnesium absorption was significantly higher in the caecum of GFL than CVL animals. However, absorption in the caecum increased less in those fed lactose diets (CVL, GFL) than in those fed the lactose-free diets (CVLO, GFLO). In the colon, magnesium absorption was only increased in GFL rats. The favorable effect of lactose on total magnesium absorption was essentially evidenced in the small intestine.

Discussion.

That TiO₂ seemed to be effective as a transit marker of unabsorbed minerals is shown by the constant R in each faecal pellet. The variations in this ratio at different levels of the digestive tract contrast with the constant value found in

the faeces. However, R shows similar values in the two animals of each experimental group killed at the same time. Therefore, these variations are not due to chance. Moreover, the curves are similar in the various experimental lots, suggesting that variations in R are related to a dietary rhythm in rat, as described by Lutton and Chevallier (1973). These variations are more accentuated in the ileum than in the caecum and colon. The low values in the ileum correspond to the longest times after the meal and, on the contrary, the high values to times of digestion. The largest variations found in the ileum were certainly related to the fact that the ileum empties and fills more quickly than the caecum and colon. However, we could not determine the origin of R variations. Would they be due to slight differences in the transit rate of the marker and the mineral which, when measured in the faeces, revealed nothing, or, on the contrary, would they result from variations in the rate of absorption and secretion, of which only apparent absorption was measured by the method we used ?

This question led us to consider the arithmetic value of R and its standard deviation, a process that penalizes the estimate and measures only important variations in apparent absorption. The existence of R variability in relation to time demonstrates that it is necessary to carry out observations during the whole light/dark cycle and that measuring only at a given time is hazardous.

The analysis of the results showed that the effects of microflora and lactose vary with the mineral and the digestive tract level studied. (Reddy (1971, 1972) reported that the mucosa of GF rats was much richer in Mg and Ca-dependent ATPases, alkaline phosphatase and CaBP, and proposed that this could explain the better absorption of calcium, phosphorus and magnesium in GF rats. Our results do not confirm this. They show that calcium and magnesium absorption was comparable in the small intestine of CV and GF rats. In the caecum of GFLO rats, significantly higher quantities of calcium and magnesium were absorbed than in CVLO rats. The factor contributing to better calcium and magnesium absorption in GF rats may be a voluminous caecum, a higher amount of soluble calcium (Andrieux, Sacquet and Guéguen, 1982) and a much longer transit time (Sacquet, Garnier and Raibaud, 1970).

Apparent absorption of calcium in the caecum of CV rats is usually low (Marcus and Lengemann, 1962 ; Urban, 1971). Some studies have shown a balance between true absorption and calcium secretion in the caecum (Petith and Schedl, 1976 ; Harrison and Harrison, 1969 ; Favus *et al.*, 1980 ; Favus, Kathalia and Coe, 1981 ; Lee *et al.*, 1980). The present study agrees with the results of Cramer (1951) who reported significant phosphorus absorption in the terminal intestine of CV rats. The site of magnesium absorption is not well known ; our results show that the terminal intestine plays an important role in its absorption. The increase in caecal size and transit time appears to favor this absorption. GF rats have higher magnesium absorption in the caecum than CV rats. The ingestion of potato starch considerably increases the caecal volume of CV rats and also increases magnesium absorption (Rayssiguier and Rémésy, 1977).

The effect of lactose on calcium absorption in the small intestine confirms other work on this subject (Wasserman and Taylor, 1976 ; Armbrecht and

Wasserman, 1976) : our results demonstrate that magnesium absorption is considerably increased by lactose. At this digestive level, the effect of lactose on the absorption of these minerals is comparable in CV and GF rats. In the hindgut, the effect of lactose is different in the two types of rat. These differences seem to be due to the fact that lactose is hydrolyzed by microflora in CVL but not in GFL rats. Various experiments point to the effect of undigestible carbohydrates on mineral absorption in the caecum or the rumen (Rayssiguier and Rémésy, 1977 ; Demigné, Rémésy and Rayssiguier, 1980 ; Rayssiguier and Poncet, 1980). Our study did not evidence such an effect. These divergences may be due to different experimental conditions and particularly to the low lactose content of our diets. However, 10 % of lactose in the diet did modify mineral absorption in the small intestine.

In the hindgut of GF rats, lactose had a favorable effect on mineral absorption in the colon but not in the caecum, as we hypothesized previously (Andrieux, Sacquet and Guéguen, 1982).

Is the action mechanism of lactose in the colon comparable to that in the small intestine ? This question is difficult to answer because we studied only apparent digestion and not secretion and absorption as such. The action of each of these processes must be determined in these various experimental groups, as has been done in conventional rat by Favus, Kathapalia and Coe (1981). Variations in alkaline phosphatase, suggested by Fournier and Dupuis to be implicated in the effect of lactose in the ileum (Dupuis, Fournier and Fournier, 1976 ; Dupuis, Digaud and Fournier, 1978), must also be studied. Fair amounts of this enzyme are present in the colon of germfree and conventional rats (Kawai and Morotomi, 1978).

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Résumé. *Effet de la flore et du lactose sur l'absorption du calcium, du phosphore et du magnésium au niveau de l'intestin terminal du rat.*

Des rats axéniques et holoxéniques, âgés de trois mois, reçoivent pendant 4 semaines, un aliment semi-synthétique stérilisé par irradiation, contenant ou non 10 % de lactose. Pendant la 5^e semaine, 0,2 % d'oxyde de titane est ajouté à l'aliment. Les rats sont alors sacrifiés à intervalle régulier pendant un nyctémère. L'excrétion comparée de l'oxyde de titane et du ⁴⁵Ca est très semblable, ce qui conduit à penser que cette substance constitue un bon marqueur du transit du calcium non absorbé. L'étude du rapport minéral/oxyde de titane au niveau de l'iléon, du caecum, du gros intestin et des matières fécales permet de déterminer l'absorption apparente du calcium, du magnésium et du phosphore à ces différents niveaux. La flore et le lactose ont des effets différents selon le minéral et le niveau du tractus digestif considérés.

— Au niveau de l'intestin grêle : la flore n'a pas d'effet sur l'absorption apparente du calcium et du magnésium, elle a un effet défavorable sur l'absorption du phosphore. Le lactose augmente l'absorption du calcium et du magnésium de manière semblable chez les rats holoxéniques et axéniques. Il a un effet favorable sur l'absorption du phosphore chez les seuls rats holoxéniques.

— Au niveau du caecum ; la flore a un effet défavorable sur l'absorption apparente du calcium et du magnésium, elle a un effet favorable sur celle du phosphore. L'ingestion de lactose réduit l'absorption du calcium et du magnésium au niveau du caecum des rats axéniques, et celle du phosphore au niveau du caecum des rats holoxéniques.

— Au niveau du côlon : les minéraux ne sont pas significativement absorbés chez les rats holoxéniques et axéniques qui ne reçoivent pas de lactose. L'ingestion de lactose provoque une augmentation significative de l'absorption de calcium de magnésium et de phosphore chez les seuls rats axéniques. Cette absorption est responsable de l'effet plus important du lactose sur l'absorption totale du calcium et du phosphore chez les rats axéniques comparés aux rats holoxéniques.

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